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BATS IN RELATION TO THE PRODUCTION OF GUANO AND THE DESTRUCTION OF INSECTS

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ECONOMIC RELATIONS OF BATS

Much has appeared in the public press in recent years about bats, their valuable deposits of guano, their alleged destruction of malarial and other mosquitoes, and the possibilities of increasing their usefulness to man by building artificial roosts for them, and many requests for information on these subjects have come to the department. L. O. Howard, chief of the Bureau of Entomology, in a paper on "Mosquitoes and Bats" read before the meeting of the New Jersey Mosquito Extermination Association in 1916[1] discussed the subject chiefly from the viewpoint of the alleged destruction of *Anopheles* in the vicinity of a bat roost near San Antonio, Tex. Further definite information on the life history and general habits of bats is still in demand from entomologists and officials in charge of health administration and general education.

The available information on the bats of North America would fill a large volume, for scattered from Panama and the Antilles to Alaska and Labrador there are about 260 species and subspecies belonging to 77 genera and 8 different families. Some of the tropical species are blood-sucking vampires and others are fruit-eaters, but nearly all the bats of the United States and farther north are insectivorous. Still the habits of the different species often differ as widely as do their structure, appearance, and range, and the useful

[1] Reprinted also in Public Health Reports, vol. 35, no. 31, pp. 1789–1795, July 30, 1920 (Reprint No. 715).

U.S. DEPARTMENT OF AGRICULTURE
From EDWARD A. FOLEY
Commissioner

habits of one species may not apply to others of the same or distant localities. Generalizations from one species can not be safely applied to others without a full knowledge of their habits. Certain bats of highly colonial habits are found in the Tropics and across the southern United States, limited mainly to the southern parts of these States, but these colonial habits do not apply generally to the more northern bats and by no means to all species in the South. This bulletin discusses the relation of colonial bats to the production of guano and the destruction of insects.[2]

THE MEXICAN FREE-TAILED BAT

Most of the sensational reports of discoveries of a great commercial value of bats as well as of sanitary benefits from their presence have been based on one species occurring in southern Texas, the Mexican free-tailed bat, *Tadarida mexicana*, long known in literature as *Nyctinomus mexicanus*, and belonging to the mainly tropical family Molossidae. In tropical and subtropical America, the West Indies, southern Europe, eastern Africa, southern Asia, Australia,

FIG. 1.—Mexican free-tailed bat (*Tadarida mexicana*), a small sooty-brown mammal with a wing spread of about 12 inches; habitant of Mexico and the arid Southwest, and the only species in the United States known to produce guano in commercial quantity

and many islands of the Pacific there are about 40 species of the genus *Tadarida*, but only 4 of these reach northward into southern United States, and only 1 is known from southern Texas.

The range of bats of the species *Tadarida mexicana* is in general restricted to the arid and semiarid sections of the Lower Austral Zone in the United States from Texas to California, and extends also throughout most of the warmer parts of Mexico. The northward limit of their range is apparently fixed by temperature or suitable food supply, and the eastward perhaps by the presence of a related species, *Tadarida cynocephala*, with very similar habits but occupying the humid division of the Lower Austral Zone from southern Louisiana to Florida and South Carolina. Two closely related forms *Tadarida femorosacca* and *Tadarida depressa*, are of rare occurrence in the Southwestern States.

The Mexican free-tailed bats are small, sooty-brown mammals spreading about 12 inches across extended wings, with projecting

[2] While this bulletin was in press a volume just published, by Charles A. R. Campbell, "Bats, Mosquitoes, and Dollars," was received. The book does not in any way alter the conclusions as set forth in these pages.

tails, short, wide ears pointing forward over the eyes like a hat rim, and short velvety fur. (Figs. 1 and 2.) Individually these bats are cleanly animals, but they have the extremely strong musky odor peculiar to the group. This permeates the air of every cave or house which they occupy in any numbers. In some houses where they are present in large numbers it becomes almost unbearably strong, and its offensiveness is increased by the added pungent odor

FIG. 2.—Mexican free-tailed bat (*Tadarida mexicana*), natural size (see also figure 1)

of ammonia from their excrement. In many houses where bats are found among the tiles of the roofs of porches and in crevices over the lintels of doorways and similar places, the odor pervading the premises often advertises their presence to anyone approaching.

In the numerous reports on bat guanos and their chemical components and value as fertilizer, samples have been listed from the caves of Africa, India, China, South America, the West Indies,

Texas, and New Mexico. In Porto Rico 110 caves have been listed, containing from 12 to 3,144 tons of guano, and many others examined containing little or no guano.[3] In no case is the species or genus of bat responsible for the guano deposits mentioned, but in every case the records of deposits lie within the range of some species of the genus *Tadarida*. This does not mean that these are the only bats producing guano of high fertilizer value in commercial quantities, but so far as known they are the only bats in America sufficiently gregarious to do so.

BAT CAVES

The most strikingly characteristic habit of Mexican free-tailed bats is that of gathering in large colonies in caves and buildings. This habit renders them valuable through the production of large quantities of guano, and possibly through the consumption of many kinds of injurious insects. They are especially numerous in southern Texas and New Mexico, where for centuries they must have occupied great numbers of the natural caves which afford ideal refuges for them. Many of the larger caves contain hundreds of thousands during the whole or a part of each year.

Some of the caves, such as the great Carlsbad Cavern, N. Mex., are mainly wintering places, where the bats hang in fall, and sleep until the warm days of spring call them out again to seek the most satisfactory feeding grounds, and to feast on their winged prey. Where the caves are in proximity to an abundance of insect life the bats remain throughout the summer, occupying the caves as roosting places during the day, and swarming out over the country in search of food at night. One such cave is about 19 miles north of San Antonio, Tex., on Cibolo Creek; and, although not very extensive, it annually yields a large quantity of guano. This and other caves west of San Antonio are occupied by great numbers of these bats, as are still others in western Texas and across southern New Mexico. Apparently this whole cave region is stocked with bats to its carrying capacity, besides providing wintering shelter for those of outlying areas, where no caves occur.

GENERAL HABITS OF THE SPECIES

Like most other bats, the Mexican free-tailed bats are almost entirely nocturnal in habits and apparently continue active throughout the night. Emerging from their roosting places after sunset, they seek their feeding grounds for pursuit of the flying insects which are their food. They are strong, rapid flyers and will even breast a stiff breeze, but in feeding they keep mainly in the vicinity of trees, buildings, or cliffs, where the air is teeming with insect life. Their progress while feeding is in quick and erratic zigzags as the insects are rapidly snapped up and devoured without a moment's pause.

During summer evenings at San Antonio, Tex., soon after sundown it is common to see great numbers of these bats flying over

[3] Gile, P. L., and J. O. Carrero, "The Bat Guanos of Porto Rico and Their Fertilizing Value": Bul. No. 25, Porto Rico Agr. Exp. Sta., pp. 66, 1918.

the town, practically all headed in one direction. They fly several hundred feet above the ground, on their way from their roost to favorite hunting grounds, often in the vicinity of water.

Bats often come into open rooms while seeking their prey and fly about with great skill, avoiding all objects and feasting on such insects as also enter through the open doors or windows, alighting for a moment on the walls or moldings to rest or devour a moth, but always careful to keep out of reach of human occupants. All of our native bats are absolutely harmless. The fear which they sometimes inspire is wholly baseless and has its origin in fictitious stories told to children and passed on from generation to generation.

At early dawn the bats return to their regular sleeping places in caves, dark rooms, under tiles or other openings in roofs, in holes and crevices among rocks, or in hollow walls of buildings. They are usually suspended by their sharp, curved hind claws and sleep until the next evening, where conditions for such a position are favorable. In other places they may be found packed in deep crevices, frequently too narrow even to admit the hand. In the roofs of small caves in the rockhills near the suburbs of Mexico City there are many bats in crevices of this kind. They commonly take possession of deserted attics and similar places in old churches or other buildings and in deserted storerooms.

Mexican free-tailed bats, like many others, have the habit of hanging up part of the night in convenient places near their roosts, as under the roofs of verandas or similar shelter, and the floor beneath is covered each morning with many scattered pellets of excrement.

Exceedingly gregarious, these bats sleep in large numbers closely packed, sometimes hundreds, or even thousands, in a solid mass, clinging to one another in such density that it is difficult to understand how those in the middle of the mass can avoid suffocation. At night, when they leave large caves or buildings where great numbers of them are living, they pour out through their chosen exits in such a swarm that in the dusk of early evening it has almost the appearance of a cloud of smoke.

Observations made in Mexico indicated it to be a common habit for certain bats to fly a number of miles from their roosts to their feeding grounds every evening, but there are no observations as to the distance the Mexican free-tailed bats may go for this purpose. Undoubtedly, however, they comb many square miles of territory about their great roosting places.

To what extent these bats migrate to take advantage of favorite winter and summer climates, or to find favorable wintering caves, is not known, but like many other bats they undoubtedly move about to seek the best seasonal conditions. At times a few wander in summer far from their regular range, as shown by records of scattered occurrences as far north as Colorado and Kansas. Extensive migrations, however, such as occur among some other more northern species of bats, are not known in this group.

HIBERNATION

In winter the Mexican free-tailed bats seek caves or buildings where the temperature is approximately constant and not too cold,

and with the first freezing nights outside they hang up for the long winter's sleep. So far as known a temperature of 50 to 55° F. in moderately dry air suits their needs for hibernation, but the limits of variation which they can endure have not been fully ascertained. Before entering hibernation they become very fat, storing up inside of their skins a rich supply of oily food material sufficient to support the greatly reduced vital processes during their torpor of winter.

Before they are fully torpid their stomachs and alimentary canals become entirely empty, their temperature gradually falls to approximately that of the surrounding air, and their circulation and respiration become greatly reduced. When fully in the embrace of the winter sleep their bodies are cold and motionless, and they are apparently dead. Thus they hang often four or five months until the warmer air of spring penetrates to their chambers and stirs their circulation to renewed activity.

In the Tropics all species appear to be active throughout the year.

FOOD HABITS

So far as known the food of the free-tailed bats consists wholly of insects, almost entirely of night-flying species captured on the wing. Moths and beetles seem generally to form the great bulk of the food, but many other insects also are eaten, and in case of an unusual abundance of any nocturnal species, these might be expected to figure largely in the food.

These bats are gluttonous feeders, and in some species 20 minutes after their appearance in the evening the stomachs have been found distended with food, the contents averaging one-quarter the weight of the animal. This would imply a capacity for at least half their weight in insects every night, and even a possibility of their actually eating their weight in them every 24 hours. Such estimates are merely suggestive and must not be used in any conclusive sense until more careful tests can be made of the food actually consumed by each species under varying conditions.

Many other bats not colonial in habits probably have a similar capacity, and over parts of the country where they exist in sufficient numbers may well have an economic value comparable to that of insectivorous birds.

If there were more caves attractive to bats and a greater food supply there would undoubtedly be more bats, whereas any considerable diminution of either factor would tend to reduce their numbers. If, however, the bats should become so numerous as to destroy most of the insect life, there would necessarily result a corresponding decrease in the bat population. The fact that bats of this species each produce only one young a year suggests a long-established and conservative balance between the food supply and the increase of the species.

GUANO DEPOSITS

Bat droppings composed entirely of insect remains and well moistened with bat urine accumulate under the roosting places, often in such large quantity as to be of value as fertilizer. When neither too wet nor too dry it is rich in nitrogen, phosphoric acid,

and other important ingredients and has a commerical value in some cases, as shown by chemical analysis, of $30 to $40 a ton.[3]

The rate of accumulation of guano varies greatly in different places, being slight in the caves where the bats merely spend the winters, but much more rapid where they live in great numbers all the year, or through the period of summer activity. In the Cibolo Creek Cave, north of San Antonio, Tex., on March 5, 1924, about an inch of fresh deposit was found on the floor where the guano had been removed during the winter. The bats had been active only a short time, and insect life had but recently become common. From this not very extensive cave there are taken out each year about 60 or 70 tons of guano, said to bring $30 a ton.

The Cibolo Creek Cave consists of a great tunnel sloping gently downward for 200 or 300 yards through the limestone formation toward the creek valley below, and widening out at the lower part in a great room some 75 feet high and 150 feet wide. Here the bats gather in vast numbers, possibly by millions, hanging to the high arched roof, and rain down their little pellets over the entire floor of the cave throughout their season of activity.

The bat roost in this cave has not only been a source of income to the owner since 1896, but also perhaps has been of importance to the community in the destruction of enough insects within the nightly range of the bats to maintain this enormous host. Nevertheless mosquitoes are said to be troublesome at times in the vicinity of the cave, and no scarcity of any kind of insect has been noticed by the residents.

In another cave on the Frio River, not far from Uvalde, Tex., about the same quantity of guano had been taken out for many years, until a fire in the guano drove out the bats and for the time ended the deposition. Other caves in the region west of San Antonio yield a somewhat smaller output of guano, and many in western Texas and southern New Mexico and Arizona have yielded it in commercial quantities.

In the great Carlsbad Cavern of southeastern New Mexico the quantity of guano removed during the 20 years from 1901 to 1921 is estimated roughly at 100,000 tons. This was the accumulation of hundreds or perhaps thousands of years, but as vast numbers of bats congregate here in fall to use the cave largely as a wintering place and as many leave again in spring for lower country and a better food supply, the guano accumulation is relatively slow, apparently not more than 1 inch a year. Many years must elapse before the deposit can again become of commercial value.

ARTIFICIAL ROOSTS FOR BATS

Interesting experiments in building roosts for the purpose of colonizing guano-producing bats (*Tadarida mexicana*) have been carried on for many years by C. A. R. Campbell, of San Antonio, Tex. An excellent description of one of these buildings (fig. 3) at Lake Mitchell is given by Doctor Howard,[4] from careful notes

[3] Gile and Carrero, op. cit.
[4] Howard, L. O., op. cit., pp. 1792–1793.

by F. C. Bishopp, in charge of the field station of the Bureau of Entomology, at Dallas, Tex., as follows:

The Campbell bat roost consists of a sort of tower set on four posts about 10 feet above the ground. According to Doctor Campbell, the size of the roost may be varied considerably. As I recall them, the dimensions of the roost at Mitchell Lake are about as follows: Twelve feet square at the bottom, the walls slanting inward toward the top, which is about 6 feet square. Height, about 20 feet. On the outside, the building is covered with drop siding with tar paper beneath. The roof is shingled and projects over the edges. It is slightly elevated so as to permit of the entrance and exit of the bats. Additional entry space is allowed entirely down one side of the building. This opening, which is about 2½ feet wide, is provided with boards slanting upward so as to exclude light to some extent but allows the bats to enter between them. The central portion of the house from the side provided with the entrance to the opposite side is unobstructed from top to bottom, thus leaving an air space about 2½ feet wide. On each side of the shaft, and running to the two other sides of the building, is a series of shelves made of matched flooring. These shelves slant upward and outward at an angle of about 30°. In the first house constructed these shelves were about 5 inches apart, but I believe in the later model they are closer together. Wire netting is tacked on top of each of the shelves so as to provide places for the bats to hang. The slant is given so as to allow the guano to roll down and drop into the center of the bottom structure, which is provided with trapdoors opening downward. This is to permit of the emptying of the manure into a wagon which is placed under the roost.

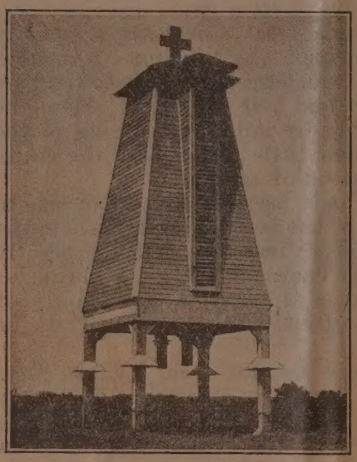

FIG. 3.—Bat roost at Mitchell Lake, Tex., occupied by a colony of Mexican free-tailed bats, estimated on March 4, 1924, to number 10,000, and yielding about 2 tons of guano a year. (Photograph by Charles H. Gable)

This roost when visited by Vernon Bailey, of the Biological Survey, in company with F. C. Bishopp and Charles H. Gable, of the Bureau of Entomology, on March 4, 1924, was occupied by a large number of bats, all of the species *Tadarida mexicana*. During the evening it was estimated that about 10,000 bats flew from the roost in the half hour between 6.45 and 7.15 o'clock. They left so rapidly from both sides of the tower that they could not be counted after the first five minutes. It seemed probable that fully 10,000 were using the roost at that time. Mr. Gable says that they were much more numerous in midsummer, but none were seen there in winter, as, according to Doctor Campbell, most of the bats disappear then and return early in spring, the first sometimes appearing about the middle of February.

About two tons of guano are taken from this roost every winter, part of which is packed in 10-pound sacks and sold at $1 a sack to local florists and individuals for use on house plants, and part of it in larger lots to local gardeners at lower prices. This roost apparently pays good dividends on the original cost and is considered a valuable investment. It is the only one of five, however, constructed in and about San Antonio that has ever been extensively

occupied by bats, and others built in Florida and Georgia had failed to attract bats up to March, 1924. So far as can be learned, the bat roost at Mitchell Lake, near San Antonio, is the only one of the eight built that has been occupied by bats, but this does not mean that others in favorable situations may not attract them.

There would be many advantages in being able to colonize bats successfully in certain localities either in artificial roosts or artificial caves and tunnels, but so far none of the experiments can be considered entirely successful. Doctor Campbell's experiment is interesting as far as it reaches, but so far it has succeeded in only one case and with only one species of bat.

The choice of roosting places by bats is evidently dependent upon factors not always readily understood. In many cave regions where bats are abundant, only certain of the numerous caves available and apparently suitable are actually occupied. Although bats may in some instances be attracted to artificially prepared roosts, prospective builders should be informed, before deciding to risk what may be a needless expenditure of funds, that there is no assurance that such structures will be used (fig. 4).

FIG. 4.—Bat roost near Military Academy, San Antonio, Tex., built by popular subscription in 1920 at a cost of $2,000, for mosquito control, but never occupied. In only one of eight such structures, from Florida to Texas, have bats taken up their abode

BUILDINGS OCCUPIED

The walls or attics of many old buildings in San Antonio, Austin, Del Rio, and other communities in western Texas are occupied by these bats. In 1923 two wagonloads of bat guano were taken out of the attic of the courthouse at Austin, and the openings carefully closed to prevent the return of the bats. The strong odor of the bats and guano rendered the building unendurable for human beings, as it has in the case of many private dwellings where the bats have taken up their abode in hollow walls or attics. To prevent their return, however, it is only necessary to close all openings in the buildings at night when the bats are out.

In the vicinity of Patzcuaro, Michoacan, at an altitude of 7,500 feet, the writer found *Tadarida mexicana* the most common species of bat, although the summer climate here was much cooler than in the localities most frequented by them. Here they were sometimes found in caves, but were more numerous among the tiles and other crevices in the roofs of the houses, and in openings in larger buildings as well. In an old building in the middle of Patzcuaro, where these bats were clinging in great numbers to the ceilings of two rooms, the owner made a regular business of gathering the guano

and selling it at the rate of 3 cents a pound, Mexican money. At the time of the writer's visit in July thousands of bats were hanging from the roof and several inches of excrement covered the floor, giving off an excessively strong odor of ammonia. The owner stated that the bats migrate when the weather becomes cold in fall and return in spring. Soon after they return they have their young.

At another place in the same town a man built a small detached room in the yard back of his house for the purpose of smoking bacon and other meat, but before he began to use it bats of this species took possession in such numbers and produced so much guano that he abandoned his original purpose and was making a good return on his investment through the sale of guano. The writer heard also of bat guano being taken from a cave on the southern slope of Mount Popocatepetl.

THE FLORIDA FREE-TAILED BAT

The following extract from a letter from Hiram Byrd, State Health Officer of Florida, to L. O. Howard, Chief of the Bureau of Entomology, under date of June 26, 1912, relative to bats taking up their abode in an uncompleted opera house begun in 1895, at Tavares, Fla., undoubtedly refers to the Florida free-tailed bat, *Tadarida cynocephala*, and if so shows that this species has the same colonial habits as the one found in Texas:

> The doors and windows of the lower floor of this opera house were securely fastened up to keep intruders out, but the upper windows were only closed by loose boards, which soon dropped out, making it easily accessible to bats. They took advantage of it, and in the course of a few years were there in countless thousands. I know of no way of estimating the number. . . . The only time I was ever there at the right hour was on a trip to Eustis. The train stopped at Tavares one-half hour before sunset and remained there something like 45 minutes. I took advantage of the occasion to see the bats emerge from the building. I had only been watching a few minutes when they began, first a single one, then two or three together, and as if the rustle started them, then they began seriously flying out of the window with incredible swiftness. There must have been at least half a hundred a second. I watched this stream of bats pouring out for half an hour or so, and was told by some of the residents of Tavares that it would continue until something like half an hour after dark, making probably two hours altogether.

About two years after the opera house had been cleaned out and converted into a packing house, Doctor Byrd made inquiries of citizens in the vicinity of Tavares and Eustis, Fla., as to whether they had experienced any appreciable difference in the number of mosquitoes since the time the bat roost in the building was at its height, and as a result of these inquiries stated that he was convinced that if there was any difference it was not noticeable.

MALARIAL CONTROL BY BATS

During many years of study of the mammals of Mexico, the writer lived a large part of the time in places where Mexican free-tailed bats were extremely abundant. Their presence in no case appeared to have the slightest influence on the prevalence of malaria. In many Mexican villages and ranches, where nearly every inhabitant was infected with malaria and where malarial mosquitoes

were swarming about the houses, these bats were living in the roofs in great numbers, apparently without having the slightest influence on the numbers of the mosquitoes. At one large cave, water in the entrance afforded a breeding place for mosquitoes, which were present in such numbers as to cause great annoyance in efforts to collect some of the bats for scientific specimens.

The assertions of Doctor Campbell that bats feed very extensively on mosquitoes, practically eliminating them in the vicinity of bat roosts and thus effectively preventing malaria, have been followed with interest by entomologists of the Department of Agriculture, and all evidence carefully weighed by Doctor Howard[5] in his paper on the subject. He has written the following two paragraphs for insertion in this bulletin:

"After a prolonged effort I have been unable to substantiate the claims made by Doctor Campbell as to the value of bat roosts in the great reduction of the mosquito population of a given locality, even in Texas. Bats obviously prefer other and larger insects. They undoubtedly swallow mosquitoes when they encounter them in flight, but only incidentally. Observations by trained men on the ground in Texas deny his claims both as to marked relief from mosquitoes or relief from malaria. One of the experts of the Bureau of Entomology stationed at San Antonio informs me (May, 1925) that of the four bat roosts at San Antonio only one is inhabited by bats, and that in endeavoring to watch the flight of the bats from this roost in the evening he was so annoyed by mosquitoes that he was obliged to abandon his observations. He further tells me that a Mexican, resident 300 yards from the roost, states that the mosquitoes are very bad at his house.

"As to other parts of the world, I am told by no less authority than Professor Grassi that in Italy the most malarious regions are precisely those where bats are most abundant."

SUMMARY

Nearly all the bats of North America north of the Tropics consume vast quantities of insects, but apparently do not exterminate any. In evaluating their services as insect destroyers it is to be borne in mind that they feed almost entirely on night-flying species.

The Mexican free-tailed bat, ranging in the United States in southern Texas, New Mexico, Arizona, and California, is extremely colonial in habits, occupying numerous caves and some buildings, and producing in places sufficient quantities of guano to be used commercially as fertilizer.

The possibility of colonizing these bats by building suitable roosts has been demonstrated in the United States, but in only one instance. Many difficulties are likely to be encountered in establishing colonies. Elaborate and expensive structures built outside the range of a colonial species or in places where the bats of the locality find other quarters preferable may not be occupied. Unless the bats can be attracted in large numbers, there is little hope of establishing a

[5] Op. cit.

worth-while colony, because of the slow rate of reproduction, there being only one at a birth.

In the single colony of bats successfully established there seems to be a profitable yield of guano. Other attempts have failed, and anyone contemplating the construction of bat roosts for commercial gain should be advised that the returns may be disappointing and wholly out of proportion to funds expended.

Mosquitoes have been found abundant in and about bat caves, and in the single case known where colonial bats have been artificially established there has been no appreciable diminution in the insect life or in the local abundance of mosquitoes. The assertions that bats will eradicate or even noticeably reduce the numbers of mosquitoes, and with them malaria, are shown by studies of their food and general life habits to be misleading and without foundation.

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